8 Comparative Analysis of Alternatives

In Section 7, each of the Site remedial alternatives were evaluated in detail using seven of the nine NCP evaluation criteria. The results of those evaluations are used in this section to compare the alternatives by identifying the advantages and disadvantages of each alternative relative to one another, consistent with EPA (1988a) guidance.

Consistent with 40 CFR300.430, each alternative is first evaluated using the threshold criteria of Overall Protectiveness of Human Health and the Environment and Compliance with ARARs (defined in Section 7.1.1). The alternatives that meet the threshold criteria are evaluated further with respect to the NCP balancing criteria: Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility, or Volume through Treatment; Short-term Effectiveness; Implementability; and Cost (defined in Section 7.1.2).

This comparative analysis includes a summary of the factors considered for each criterion, which are described in more detail in Section 7. This analysis then identifies the key differentiating factors between alternatives. For threshold criteria, each alternative is identified as meeting or not meeting the criteria. For all of the balancing criteria except cost, each alternative is evaluated using a qualitative scale to rate the relative degree (i.e., low, moderate, high) to which the alternative meets the criteria requirements. For cost, the evaluation is based on estimated capital and long-term (OM&M) costs[1]. A summary of the comparative rating of the alternatives is provided in Table 8-1.

The comparative analysis is presented below.

8.1 Threshold Criteria Comparison

This section presents a comparative analysis of the two NCP threshold criteria: Overall Protection of Human Health and the Environment (Section 8.1.1) and Compliance with ARARs (Section 8.1.2).

8.1.1 *Overall Protection of Human Health and the Environment*

This threshold criterion addresses the overall ability of each alternative to eliminate, reduce, or control potential exposures to hazardous substances in both the short and long term, and comply with ARARs, and evaluates whether the alternative achieves the RAOs for protection of human health and the environment.

A comparison of the alternatives is summarized for RAOs for protection of human health (Section 8.1.1.1) and protection of the environment (Section 8.1.1.2), followed by an overall summary of how the alternatives compare to one another for this criterion (Section 8.1.1.3).

The adequacy of how the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment are eliminated, reduced, or

[1] Note that the cost effectiveness of the remedial alternatives is not evaluated in the FS but will be considered during selection of a preferred remedy.

controlled through treatment, engineering, or institutional controls for each alternative describes its **protectiveness**. However, the **Overall Protection of Human Health and the Environment** threshold criterion draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs (EPA, 1988). As described in Section 7.1.1.1, the Overall Protection of Human Health and the Environment criterion was rated as "No," or "Yes," based on consideration of whether: 1) all exposure pathways are mitigated (i.e., the alternative is protective); 2) the alternative provides long-term effectiveness and permanence; 3) does not pose a high short-term risk; and 4) meets ARARs or is waived from the requirement for compliance with an ARAR.

8.1.1.1 RAOs for Protection of Human Health

Alternative 1 does not achieve any of the RAOs for protection of human health. Alternatives 2 through 6 will achieve the RAOs for human health that focus on protection of beach users, subsistence fishers, upland residents, commercial workers, and construction workers. However, the RAO to restore groundwater to its highest beneficial use (drinking water) by meeting MCLs cannot be achieve by Alternatives 2 through 6 because PTWs that cause the groundwater contamination remain in place to varying degrees. Alternatives 7 through 10 treat or remove all known PTWs[2], and therefore, may restore groundwater to meet drinking water standards for one or more COCs throughout most of the plume, if not all of the plume. For these alternatives, institutional controls that specifically address use of drinking water would not be fully required in perpetuity.

There would be a heavier reliance on institutional controls that would control the disturbance of the soil cap from activities that may compromise the integrity of the soil cap for Alternatives 2 through 6; whereas a soil cap may not be needed for Alternatives 7 through 10, where all PTWs are removed or treated[3]. Alternatives 2 through 10 would all initially rely on institutional controls to control exposure to contaminated sediment and surface water by restricting activities that could cause damage to sediment caps that mitigate the release of contamination into surface water. However, there would be a lesser reliance on caps and they may not be required in perpetuity for Alternatives 7 through 10 because all PTWs are removed from the aquatic environment.

8.1.1.2 RAOs for Protection of the Environment

Alternative 1 does not achieve any of the RAOs for protection of the environment. Alternatives 2 through 10 will achieve the RAOs for the environment that focus on protection of upland wildlife and plants, as well as aquatic benthos, fish, plants, and aquatic-dependent wildlife. There would be a heavier reliance on institutional controls

[2] All "known PTWs" refers to PTWs identified during site investigations supporting the FS. It is anticipated that the lateral and vertical extent of PTWs in both the upland and aquatic areas of the Site would be based on a field performance standard that would be developed during remedial design. It is also anticipated that small volumes and masses of DNAPL residuals could be inadvertently missed during remedial implementation.

[3] A full upland soil cap may not be necessary in other alternatives where portions of the upland soils have been excavated or treated, and therefore, do not pose a dermal or inhalation exposure risk.

would control the disturbance of the soil cap from activities that may compromise the integrity of the soil cap for Alternatives 2 through 6; whereas a soil cap may not be needed for Alternatives 7 through 10, where all known PTWs are removed or treated. Alternatives 2 through 10 would all rely on institutional controls to control exposure to contaminated sediment and surface water by restricting activities that could cause damage to sediments caps that mitigate the release of contamination into surface water. However, there would be a lesser reliance on caps in perpetuity for Alternatives 7 through 10 because all known PTWs are removed from the aquatic environment.

8.1.1.3 Overall Protection of Human Health and the Environment Summary

Alternatives 1 through 6 would not meet this threshold criterion because they leave varying amounts of known and accessible PTWs in place and as a result, would never restore groundwater to its highest beneficial use, and rely heavily on institutional controls to be protective. Alternatives 7 through 10 would meet this threshold criterion because all known PTWs are removed or treated. They would also likely comply with the MCL ARAR (see Section 8.2), and in the event MCLs are not determined to be achievable for all COCs, Alternatives 7 through 10 would be candidates for a TI waiver, as all known PTWs are addressed under these alternatives.

8.1.2 *Compliance with ARARs*

This threshold criterion assesses whether each alternative would attain the identified chemical-, action-, and location-specific ARARs and other “To Be Considered” (TBC) criteria, advisories, and guidance presented in Section 4.1. As discussed in Section 7.1.1.2, it would be expected that all alternatives, except Alternative 1 (No Action), would comply with all ARARs except the SDWA, which requires achievement of groundwater MCLs throughout the Site. The degree to which MCLs would be achieved varies dramatically based on the PTWs addressed for each alternative.

As described in Section 7.1.1.2, the Compliance with ARARs criterion was rated as “No”, “Yes with TI Waiver”, or “Yes”.

8.1.2.1 Compliance with the MCL ARAR

To assess compliance with the SDWA, groundwater modeling was used to predict the volumes of contaminated groundwater exceeding the MCLs for benzene, benzo(a)pyrene, and arsenic 100 years following implementation of each alternative. Results are provided on Figure 7-1 and are summarized below:

- Benzene was predicted to exceed its MCL after 100 years for Alternatives 1 through 7 and 9. It was predicted to achieve its MCL after 28 years for Alternative 8, and after 14 years for Alternative 10. EPA believes that the timeframes for Alternatives 8 and 10 may also be relevant for Alternatives 7 and 9, given that the extent of benzene MCL exceedances based on empirical data are smaller than the model predicts, *in situ* solidification is likely to oxygenate the subsurface and aid in volatile attenuation, and the resulting solidified materials are not considered to be aquifer materials.
- Benzo(a)pyrene was predicted to exceed its MCL in groundwater after 100 years for all alternatives except for Alternative 10. For Alternative 10, the groundwater model predicted that the benzo(a)pyrene MCL would be achieved when construction is complete. EPA believes that the

benzo(a)pyrene MCL could also be achieved in a reasonable timeframe with Alternatives 7, 8, and 9. Empirical data indicate there are currently a few instances of very low detections of benzo(a)pyrene above the MCL outside the known DNAPL areas. The reason the groundwater model predicts MCL exceedances after 100 years for Alternatives 7, 8, and 9 is that it assumes a baseline condition where benzo(a)pyrene exceeds the MCL outside of the DNAPL areas; therefore, even when the DNAPL source is removed, the model assumes that the MCL exceedances remain and do not degrade over time. Based on empirical data, EPA believes that if the DNAPL source is addressed, then benzo(a)pyrene would also be addressed.

- Arsenic was predicted to exceed its MCL in groundwater 100 years following implementation of all alternatives. For Alternatives 7 through 10, EPA believes that if the known DNAPL source is removed or treated, arsenic would also be more significantly reduced than the modeling predicts.

Alternative 2 slightly reduced the estimated volume of groundwater exceeding MCLs after 100 years (by 13 percent for the aggregate plume). Alternative 1 (No Action) is used as a baseline against which the plume reductions achieved by the other alternatives are compared. The volume of groundwater exceeding MCLs after 100 years would be moderately reduced by implementing Alternatives 3 through 6 (ranging from 33 to 50 percent aggregate reduction) and significantly reduced by implementing Alternatives 7 through 10 (ranging from 79 to 93 percent aggregate reduction).

8.1.2.2 Technical Impracticability Waiver

Alternatives 1 through 6 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTW is readily accessible and removal or treatment is feasible with currently available engineering technology. Alternatives 7 through 10 may or may not require a TI waiver; however if a TI waiver were needed, a TI waiver could be granted for Alternatives 7 through 10.

8.1.2.3 Compliance with ARARs Summary

Alternatives 1 through 6 do not satisfy the threshold criteria for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic would not be met throughout the plume nor could a TI waiver be granted. Alternatives 7 through 10 may achieve MCLs for one or more COCs in a reasonable timeframe, and if necessary, a TI waiver could be granted.

8.1.3 *Threshold Criteria Summary*

Overall protection of human health and the environment and compliance with ARARs serve as threshold determinations in that they must be met by any alternative in order for it to be eligible for selection (EPA, 1988). As discussed in Section 7.1.2, the Site has some recalcitrant COCs and a very complex, heterogeneous subsurface. Both contribute to challenges in developing and selecting remedial alternatives that are appropriate to the Site. Conversely, based on years of site investigations culminating with the RI in 2009, it has been determined that the extent of PTWs at the Site is limited to shallow (less than 35 feet) alluvium and is accessible (as opposed to, for example, deep in fractured bedrock).

EPA agreed during the FS scoping process to allow development of a wide array of alternatives to address the remedial problems at the Site even though it was uncertain prior to the evaluation of alternatives whether any of the alternatives would satisfy threshold criteria and potentially require a waiver of ARARs.

As described above, Alternatives 1 through 6 do not meet either threshold criteria. However, Alternatives 7 through 10 satisfy the overall protection of human health and the environment criterion, and would meet all ARARs or be granted a TI waiver if monitoring indicated that one or more of the COCs in groundwater would not achieve MCLs. Section 7 includes the detailed analysis used to evaluate these threshold criteria that drew on evaluation of the balancing criteria and interpretation of groundwater modeling. Because Alternatives 1 through 6 do not satisfy the threshold criteria, they are not carried forward in the Balancing Criteria comparison.

8.2 Balancing Criteria Comparison

This section includes a comparison of Alternatives 7 through 10 with respect to the five balancing criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost).

8.2.1 *Long-Term Effectiveness and Permanence*

This NCP balancing criterion evaluates each alternative's long-term effectiveness and permanence by assessing the magnitude of residual risk remaining after implementation and the adequacy and reliability of engineering and institutional control measures to manage those potential residual risks. The magnitude of residual risk was evaluated in the context of untreated waste and treatment residuals left onsite after remediation. It is presented in terms of the degree to which PTW sources are remediated and the percent the contaminated groundwater plume is reduced. The adequacy and reliability of controls were evaluated by examining the complexity and efficacy of requirements for long-term operation, maintenance and monitoring of the alternative. The comparison of alternatives on these general criteria is described below.

8.2.1.1 Magnitude of Residual Risk

Assessment of the magnitude of residual risk following remedy implementation included a comparative evaluation of alternatives based on the respective total volumes of DNAPL removed or treated (Figure 7-2). A secondary factor that was considered is the effectiveness of groundwater treatment among the alternatives based on the predicted reduction in contaminant plume volumes 100 years after implementation of the alternative (Figure 7-3). This was considered secondary to the volume of DNAPL removed or treated because the majority of contaminant mass at the Site, and the most toxic materials, are contained in the PTWs.

The primary differences in which Alternatives 7 through 10 would remove or treat contaminated materials at the Site are summarized as follows:

- Alternatives 7 through 10 would remove or treat all known PTWs. Alternatives 9 and 10 would further remove or treat additional contaminated Shallow Aquifer materials in the upland and contaminated sediment in the nearshore area.

- Alternatives 7 through 10 would significantly reduce the volume of organic COCs in groundwater. Alternatives 7 and 9 would each reduce benzene by 97 percent; and naphthalene by 89 and 86 percent, respectively. Alternatives 8 and 10 would each reduce benzene and naphthalene by 100 percent. Alternative 10 would also reduce the benzo(a)pyrene plume by 100 percent; however, while the benzo(a)pyrene plume reduction estimates are lower for Alternatives 7 through 9, EPA believes that if all PTW is treated or removed, the benzo(a)pyrene plume would be reduced by 100 percent for Alternatives 7 through 9 as well. Because Alternatives 9 and 10 would treat or remove contaminated soils and sediment beyond the PTW footprint, they may reduce the uncertainty that PTW would be inadvertently missed. As noted previously, EPA believes that it is likely that plume volumes, in general, would be reduced more substantially given that the model overestimates the groundwater plume volumes based on comparison to empirical data.
- Alternatives 7 through 9 would result in modest plume reduction for arsenic, ranging from 11 to 21 percent. This is likely due to not using modeled source propagation to define the initial conditions for arsenic (see Appendix A, Section A3.2). Therefore, the groundwater model results are considered highly uncertain. Alternative 10 would reduce the arsenic plume volume by 65 percent primarily because the alternative removes the Shallow Aquifer materials with arsenic exceeding MCLs; the remaining 35 percent represents arsenic in the Deep Aquifer. EPA believes that the same would be true for Alternative 9, as the identical contaminated materials would be addressed via both *in situ* solidification (which would immobilize arsenic) and removal. Arsenic that exists in the Deep Aquifer is anticipated to remain and not degrade; however, it is anticipated that if the PTW source is removed, the reducing conditions that may have caused liberation of arsenic from the natural environment would be changed and therefore the “source” of arsenic would be removed.

For all alternatives, unacceptable risks would remain in place should exposure occur, until COCs are returned to acceptable levels.

In summary, Alternatives 7 through 10 would treat all known PTWs. Although Alternatives 9 and 10 treat or remove more contaminated materials, the effect on the organic COC plume reduction would not be significant over Alternatives 7 and 8. Alternative 10 provides a more substantial decrease in the volume of the arsenic plume as compared to Alternatives 7 through 9; however, it is anticipated that arsenic would attenuate following PTW source removal, though there is a higher degree of uncertainty around the fate and transport of arsenic following PTW source removal than that of the organic COCs.

8.2.1.2 Adequacy and Reliability of Controls

This factor assesses the reliability of controls used to manage contaminated materials that would remain at the Site after remedy implementation. Controls would include engineered controls such as caps, institutional controls, and long-term monitoring. Differences in the reliability of controls include the following:

- Controls in upland areas are generally considered much more reliable than controls in aquatic areas because access and use of upland areas could be more easily controlled and enforced, and would be easier to access for monitoring and maintenance.
- Controls that rely on treatment (e.g., reactive sediment covers) to be effective are considered to have a greater risk of failure than controls that rely on providing a physical barrier, because treatment media can lose effectiveness over time (e.g., by becoming saturated with contaminants). These measures typically require more frequent monitoring to evaluate effectiveness and allow for maintenance as needed, and must either be designed conservatively or planned for periodic replacement. The concern is greatest for technologies that use reactive materials for organic substances such as PAHs, which have a very wide range of hydrophilic properties. *In situ* reactive treatment technologies for sediment are fairly new, with limited long-term (i.e., past 10 years) field experience; therefore, there is more uncertainty regarding maintenance and replacement frequency, and how the maintenance/replacement impacts the environment, particularly the shallow aquatic environment (e.g., habitat disturbance, release of COCs).
- Technologies that rely on long-term monitoring to ensure the viability of controls (e.g., *in situ* stabilization, soil caps, reactive sediment covers, engineered sand caps, ENR) are considered to have a greater risk of failure than technologies that do not require long-term monitoring. Monitoring frequency and techniques can greatly increase the cost of long-term care of remedies and are absolutely necessary to ensure protectiveness. A balance needs to be found between monitoring magnitude and frequency and assurance of protectiveness; if controls fail, the degree of monitoring would affect the significance of the magnitude and/or duration of potential exposure.

Alternatives 7 through 10 would include similar types of engineering controls. These engineering controls would include an upland cap, an engineered sand cap, and ENR placed over generally similar areas. However, the engineered sand cap area would be less for Alternatives 9 and 10 than Alternatives 7 and 8 due to greater dredging of contaminated sediments. In dredging areas, the engineered sand cap would be eliminated; however, a residuals cover would be placed following dredging. In all cases, the engineered sand cap may not need to perform in perpetuity, assuming that once the PTWs were removed or treated, groundwater would attenuate to levels that would be protective of surface water.

For Alternatives 7 through 10, institutional controls related to groundwater, sediment, and surface water use may only be needed until cleanup numbers are met. Alternative 10 requires the fewest institutional controls because all known PTWs and associated contaminated shallow aquifer materials would be removed.

8.2.1.3 Overall Long-Term Effectiveness and Permanence Ranking

The long-term effectiveness and permanence rating is based on consideration of both the magnitude of residual risk associated with any contamination remaining at the Site following implementation of the remedy and the reliability of controls.

The differences in long-term effectiveness and permanence among the alternatives are summarized as follows:

- Alternatives 7 through 10 would greatly reduce the magnitude of residual risk through removal or treatment of all known PTWs.
- Alternatives 9 and 10 remove or treat additional contaminated soil and sediment, but the vast majority of the contaminant mass is present in the PTWs. With the exception of a smaller residual arsenic plume for Alternative 10, all of these alternatives provide for similar and substantial reductions in the volume of contaminated groundwater.
- Alternatives 7 through 10 would include similar engineering and institutional controls; however, the controls would be more effective for Alternatives 9 and 10, where the remedies would reduce the quantity of contamination remaining. For instance, there is less risk in the event of technology failure (e.g., cap disturbance during a seismic event or violation of restrictive covenants) if there is less residual contamination. In the event that a control measure fails, all alternatives would have monitoring to identify the failure and to repair the measures.
- Alternatives 7 through 10 are all rated high for this criterion.

8.2.2 *Reduction of Toxicity, Mobility, or Volume through Treatment*

This NCP balancing criterion evaluates the degree to which each remedial alternative reduces toxicity, mobility, or volume through treatment.

The comparative rating of alternatives for this criterion, presented in Table 8-1, was based primarily on the expected toxicity, mobility, or volume reduction through treatment of PTWs, primarily using the estimated total volume of DNAPL treated as a metric.

As a secondary factor for evaluating this criterion, the alternatives were differentiated based on the expected reduction in volume and mobility of contaminated groundwater resulting from treatment, based on groundwater modeling results. Groundwater treatment metrics were considered secondary to the PTW treatment metric because the majority of contaminant mass at the Site, and the most toxic materials, are contained in the PTWs.

8.2.2.1 Treatment Processes Used and Materials Treated

Alternatives 7 and 9 include upland DNAPL/soil *in situ* solidification. Alternatives 8, 9, and 10 include onsite *ex situ* thermal treatment of PTW soils and sediments. Alternatives 7 through 10 all include residuals covers in areas of the aquatic environment that have been dredged. Alternatives 9 and 10 include larger dredge areas than Alternatives 7 and 8. Alternative 7 includes treatment of 85 percent of PTWs (with the remaining 15 percent being disposed of at an off-site landfill). Alternatives 8 through 10 include on-site treatment of all PTWs, either *in situ* or *ex situ*. Therefore, Alternatives 8 through 10 rank slightly higher than Alternative 7.

8.2.2.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 7, approximately 377,500 gallons of DNAPL would be treated by *in situ* solidification. Under Alternative 9, approximately 104,400 gallons of DNAPL would be treated by *in situ* solidification; approximately 340,700 gallons of DNAPL would be subject to on-site thermal treatment. For Alternatives 8 and 10, all of the DNAPL (445,100 gallons) would be subject to on-site thermal treatment. The amount of DNAPL that may be sorbed onto the reactive residual covers is unknown but expected to be minimal. Alternatives 9 and 10 would also treat contaminated soil, but the mass of contaminants in the soil is expected to be negligible compared to PTWs. It is likely that some residual contamination would remain given the complexity of the Site and the volumes of treatment for all of these alternatives. Alternatives 9 and 10 would rank slightly higher than Alternatives 7 and 8 because of the additional contaminants that may be treated beyond the known PTW and because a larger treatment area would increase the likelihood that all PTW is found.

8.2.2.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternatives 7 would reduce the mobility of upland DNAPL through *in situ* solidification. Alternative 9 would also reduce the mobility of deeper DNAPL (generally deeper than 15 feet) through *in situ* solidification, but would reduce the toxicity, mobility, and volume of shallow DNAPL via on-site thermal treatment, which volatilizes the organic compounds. Alternatives 8 and 10 would reduce the toxicity, mobility, and volume of all known DNAPL via on-site thermal treatment. The effectiveness of thermal treatment on arsenic is unknown; however, arsenic would be immobilized with *in situ* solidification. This FS assumes that thermal treatment would remove DNAPL, but the treated soil may still exceed PRGs.

The estimated percent reductions in contaminant mass and mass flux for Alternatives 7 through 10 are as follows:

Percent Contaminant Mass Reduction				
Alternative	**Benzene**	**Naphthalene**	**Benzo(a)pyrene**	**Arsenic**
7	100	100	98	24
8	100	100	92	13
9	99	100	99	29
10	100	100	99	53

Percent Contaminant Mass Flux Reduction				
Alternative	**Benzene**	**Naphthalene**	**Benzo(a)pyrene**	**Arsenic**
7	100	100	99	6
8	100	100	99	6
9	100	100	100	62

Percent Contaminant Mass Flux Reduction				
10	100	100	100	86

Alternatives 7 through 10 would all be highly effective for treating organics. The groundwater model predicts more modest reductions for arsenic. Alternatives 9 and 10 would be more effective in that they would address areas with MCL exceedances for arsenic that are outside of the footprint of known PTWs.

8.2.2.4 Degree to which Treatment is Irreversible

Alternatives 8, 9, and 10, which employ thermal treatment to varying degrees rank slightly higher than Alternative 7, which relies solely on *in situ* stabilization as its treatment technology. Thermal treatment is irreversible. While *in situ* solidification is also expected to be irreversible, dissolved-phase COCs that may leach from the solidified block can be assumed not be to be irreversibly treated.

8.2.2.5 Type and Quantity of Residuals Remaining after Treatment

For Alternative 7, the solidified matrix is not considered to be post-treatment residual or untreated waste; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown. For Alternatives 8, 9, and 10, thermally-treated DNAPL-impacted soil and sediment would remain onsite, and mixed with the soil/sediment matrix would comprise between approximately 268,400 cy for Alternative 8, and 878,500 cy for Alternative 10. Residual contaminant concentrations in soil would be expected to be low but may exceed PRGs depending on the effectiveness of treatment. Alternative 9, which includes *in situ* stabilization of deeper Shallow Aquifer materials, may also contribute an unknown amount of residual dissolved-phase contamination.

8.2.2.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternatives 7 through 10 all satisfy the statutory preference for treatment as a principal element, as in each alternative, the majority of the contaminant mass is treated.

8.2.2.7 Overall Reduction of Toxicity, Mobility, or Volume Through Treatment Ranking

Alternatives 7 through 10 would employ two treatment methods for PTW:

- *In situ* solidification of upland PTWs (Alternatives 7, and 9); and
- On-site thermal treatment of PTWs (Alternatives 8, 9, and 10).

For the purposes of this FS, treatment by thermal destruction technologies (incineration/ thermal treatment) was rated higher than *in situ* solidification, because preference was given to technologies that permanently destroy the COCs (thus reducing toxicity, mobility, and volume) over technologies that permanently bind COCs.

Groundwater treatment would be achieved through treatment of PTWs and surrounding contaminated soil or sediment as described above. In addition, groundwater pump and treatment systems would be used to treat Site groundwater along the shoreline for Alternative 10.

Alternatives 7 through 10 were rated with respect to this criterion as follows:

- Alternatives 7 and 8 would treat all PTWs and greatly reduce the volume and mass flux of contaminated groundwater. Alternative 7 would achieve treatment through *in situ* solidification, while Alternative 8 would achieve treatment through on-site thermal treatment. Both alternatives are rated high for this criterion. Alternative 8 satisfies this criterion to a slightly higher degree than Alternative 7 due to the more permanent nature of treatment and reduction in contaminant volume.
- Alternatives 9 and 10 would treat all PTWs and also would treat a substantial volume of contaminated soil and sediment. Alternative 9 would use a combination of *in situ* solidification and on-site thermal treatment, while Alternative 10 would use on-site thermal treatment. Alternative 10 also would achieve the greatest reduction in groundwater plume volume.
- Alternatives 7 through 10 are rated high for this criterion.

8.2.3 *Short-Term Effectiveness*

This NCP balancing criterion is used to evaluate the effects and potential risks associated with remedial alternative implementation, considering the protection of the community, the protection of workers, and potential impacts to the environment. This criterion also considers the effectiveness of mitigative measures (i.e., measures such as BMPs that would reduce the short-term impacts of the alternatives) and the time until RAOs would be achieved.

In general, short-term impacts increase with the quantities of contaminated materials removed or handled. Many impacts can be adequately managed through standard construction practices such as health and safety programs and BMPs, but the potential for increased exposures, or releases to the neighboring community, on-site workers, and the environment could occur due to failure of construction equipment and/or protective controls when remediating greater volumes of contaminated materials. In addition, several impacts would be challenging to control, including the following:

- Vapor and dust emissions, from disturbance of contaminated materials during excavation, dredging, and (to a lesser degree) *in situ* solidification. These could result in noxious odors and exposure of the community to volatile compounds.
- Vapor and dust emissions from handing, stockpiling, and transporting contaminated materials off-site (Alternative 7).
- Alternatives involving on-site thermal treatment of contaminated materials (Alternatives 8, 9, and 10) also would have the potential for air emissions from on-site handling and treatment; however, these emissions would be more easily controlled by available process technologies employed in the treatment train.

- Water quality impacts from capping and dredging would be reduced as much as possible by implementing hydraulic dredging with silt curtain/oil boom controls in the aquatic area and providing barrier containment with sheet piles around mechanical dredge areas in the nearshore.
- RAOs, with the exception of restoring groundwater to its highest beneficial use, would be achieved at the end of the construction period. Meeting this RAO would require an uncertain period of time following the end of construction, but it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver could be granted, if necessary.
- "Quality of life" impacts to the community from construction noise, traffic, and aesthetics could result. However, these are not related to risks caused from potential exposure to contaminated media.

The estimated design and construction duration for each alternative is shown on Figure 7-5. The short-term effectiveness of Alternatives 7 through 10 is compared in Table 8-1 and summarized as follows:

- Alternative 7 involves *in situ* stabilization of known upland PTWs and dredging of known aquatic PTWs and would have a construction period of approximately 4.5 years. Dredged materials would be trucked offsite for disposal. These activities all create the potential for exposure to dust and vapors for both the community and Site workers; however no unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. The greatest impacts would be expected in the aquatic environment; however, BMPs would be used to minimize water quality impacts and habitat recovery would be expected to occur relatively quickly following placement of the residuals cover over dredged areas. Therefore, Alternative 7 is rated as moderate for short-term effectiveness.
- Alternative 8 involves excavation of upland PTWs, the same dredging of PTW sediments as Alternative 7, and on-site thermal treatment of all removed PTW materials. Alternative 8 would have a longer construction period (approximately 5.5 years). It would include additional materials handling and stockpiling of PTW materials, as well as air emissions from on-site treatment; therefore, it would likely have higher short-term impacts than Alternative 7. Alternative 8 is rated low for short-term effectiveness.
- Alternatives 9 and 10 would have the greatest potential short-term impacts to workers, the community, and the environment, and would have very long construction durations (10 and 12 years, respectively). Therefore, they are rated low for short-term effectiveness. Alternative 10 would have greater short-term impacts than Alternative 9 due to the much greater volumes of contaminated soil and sediment that would be removed under Alternative 10.

8.2.4 *Implementability*

This NCP balancing criterion is used to evaluate the relative implementability of Alternatives 7 through 10, focusing on their technical feasibility, administrative feasibility; and the availability of services and materials.

In general, implementability decreases with increased complexity of the alternatives. With the exception of the RCM caps, the technologies used by all alternatives are proven technologies that have been implemented at other, similar sites and could be implemented at the Site. Differences in complexity include the following:

- Alternatives involving *in situ* solidification (Alternatives 7 and 9) would require bench and/or pilot testing of potential amendment mixtures to determine proper mixes to optimize effectiveness, though this is not considered to be an implementability concern.
- Alternatives involving deep excavations (Alternatives 8 and 10) would have substantially increased complexity due to robust shoring and dewatering systems. The conceptual shoring system for Alternative 10 would include 95-foot-long sheet piles (based on the analysis performed in Section 6), which are not readily available and could result in transportation challenges.
- Alternatives involving on-site thermal treatment of soil or sediment (Alternatives 8, 9, and 10) would require treatability testing. On-site thermal treatment would also require air emission controls and extensive monitoring.

All alternatives would require coordination with numerous federal and state regulatory agencies, during remedial design, to ensure that all ARARs (including ESA consultation and substantive compliance with Section 401 and 404 of the CWA), policies, and regulations are met. Coordination with these agencies, by EPA, has become routine in the Puget Sound area of Washington. Little coordination is expected during remedial action because reasons for coordination would be addressed during remedial design. Maintenance of caps would require coordination with the DNR and the Muckleshoot Tribe regarding future aquatic land use and Tribal treaty rights. Alternatives with longer construction durations and/or more construction elements would generally require more administrative coordination and have a greater potential for technical problems and schedule delays.

The implementability of each alternative is compared in Table 8-1 and summarized as follows:

- Alternative 7 would have the shortest construction period and the fewest construction elements compared to Alternatives 8 through 10. This alternative is rated high for implementability.
- Alternative 8 would involve significantly greater implementability challenges than Alternative 7 due to the complexities of shoring and dewatering extensive excavations and providing on-site thermal treatment of a large volume of material. This alternative is rated low for implementability.

- Alternatives 9 and 10 would involve the largest soil and sediment removal volumes and very extensive in-water and upland construction activities. The scope of these activities would encounter severe technical and administrative challenges. These alternatives are rated low for implementability.

8.2.5 *Cost*

Cost estimates were developed for each alternative per EPA guidance (EPA 2000) as described in Section 7.1.2.5 and detailed in Appendix D. To compare alternative costs for this criterion, this section summarizes the cost of each alternative and identifies the primary components that result in significant cost differences between the alternatives. This section also identifies the relative contribution of long-term (OM&M) costs for each alternative. Consistent with Section 7, this section only references NPV costs using a 1.6 percent discount rate. See Appendix D for two versions of the cost estimates for each alternative: one based on NPV and one with no discount rate applied. In general, not adjusting costs to NPV results in estimated long-term costs roughly 40 percent higher.

The estimated present worth cost for each alternative, in 2013 dollars and using a discount factor of 1.6 percent, is listed in Table 8-1. Capital and OM&M costs are also provided in Table 8-1. In general, alternatives involving more extensive treatment of PTWs would have higher capital and lower long-term costs. Among treatment technologies, *in situ* solidification is significantly cheaper on a unit cost basis than removal and off-site disposal or on-site thermal treatment. Alternative costs ranged as follows:

- Alternative 7 capital ($78M) and total ($80M) costs are based on treatment of all upland PTWs via *in situ* solidification. The OM&M cost ($2.7M) is based on groundwater monitoring and inspection/maintenance of the upland cap, engineered sand cap, and ENR.
- Alternative 8 would have much higher capital ($137M) and total ($140M) costs than Alternative 7 because treatment of the same amount of PTWs would be accomplished using removal and on-site treatment, which has a much higher unit cost than *in situ* solidification. The OM&M cost ($2.7M) is the same as Alternative 7.
- Alternative 9 would have significantly higher capital ($259M) and total ($262M) costs compared to Alternative 8 because of the much more extensive treatment through *in situ* solidification of deep soil and removal/on-site treatment of contaminated sediments. The OM&M cost ($2.7M) is the same as Alternatives 7 and 8.
- Alternative 10 would have the highest capital ($380M) and total ($409M) costs of the alternatives. These costs are much higher than Alternative 9 because all contaminated soils would be removed and treated onsite, which has a greater unit cost than *in situ* solidification. The OM&M cost ($29M) is much higher because of long-term operation of a groundwater pump-and-treat system.

8.3 Comparative Analysis Summary

In this FS, 11 remedial alternatives were developed and evaluated as described above. The alternatives provide a broad range of actions, including various levels of containment, removal, and/or treatment, consistent with EPA guidance (EPA 1988a). The detailed analysis in Section 7 evaluates each alternative against seven NCP criteria: the threshold criteria of overall protection and ARAR compliance, and the balancing criteria of long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. This evaluation is summarized in Table 7-3.

Alternatives 1 through 6 do not meet the threshold requirements for overall protection and ARAR compliance. However, Alternatives 7 through 10 satisfy both the Overall Protection of Human Health and the Environment criterion, and would meet all ARARs or be granted a TI waiver if monitoring indicates that one or more of the COCs in groundwater would not achieve MCLs. Because Alternatives 1 through 6 do not satisfy the threshold criteria, only Alternatives 7 through 10 were carried forward in the balancing criteria comparison.

Alternatives 7 through 10 are all rated high for long-term effectiveness and permanence, and reduction of toxicity, mobility, or volume through treatment. For short-term effectiveness, Alternative 7 is rated moderate, while Alternatives 8 through 10 are rated low. For implementability, Alternative 7 is rated high, while Alternatives 8 through 10 are rated low. Alternative 7 is projected to have the lowest cost. Alternative 8 is nearly twice the cost of Alternative 7; Alternatives 9 and 10 are approximately 3 and 5 times higher than Alterative 7. This evaluation is summarized in Table 8-1.

Certain statutory requirements for CERCLA remedial actions (such as cost effectiveness or using permanent solutions to the maximum extent practicable) are not evaluated in the FS, but are important considerations during selection of a final remedy. EPA will select a preferred remedy and prepare a proposed plan based on the analysis presented in this FS, risk management considerations, and statutory requirements for remedial actions. The preferred remedy may be one of the alternatives described in the FS or a combination of elements from different alternatives, as appropriate. State, tribal, and community acceptance of the preferred remedy will be evaluated in the ROD once comments on the FS and proposed plan are received.